SCIENCE
MAKES LIFE
BETTER
Science
Prep-3
مناهج
(FOUNDATION COURSE)
By Mrs.
Fatma Fathy Saad
WhatsApp:
01274112011
YouTube:
manaheg390
Manaheg
Learn Today
Lead Tomorrow
D.M.RAZK
موقع الدكتور محمد رزق معلم الكيمياء التعليمي

Science Prep -3
First term

Let's Remember Together

Prepared by:

Ms. Fatma Fathy Saad

Manaheg

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Manaheg YouTube Channel

WhatsApp: 01274112011

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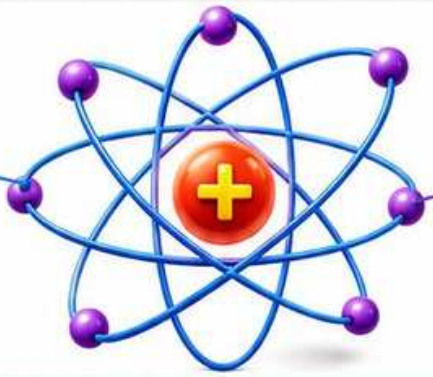
The atom

The building and structural unit of all matter.

Structure of the Atom

The Nucleus

It occupies a very small space in the atom and contains two types of particles: **protons** and **neutrons**.



Electrons

Extremely small particles that revolve around the nucleus at high speeds in energy levels.

Relative electric charge of the components of the atom:

Proton	Neutron	Electron
p	n	e^-
Positively charged particle (+)	Neutrally charged particle (±)	Negatively charged particle (−)

- The charge of a proton is **equal** to the charge of an electron in **quantity** but **opposite** in type.

G.R.? **The nucleus of an atom is positively charged.**
Because the nucleus contains positively charged protons and neutrally charged neutrons.

The number of positive protons p (=) number of negative electrons e^-

G.R.? **The atom is electrically neutral in its normal state.**
Because the number of negatively charged electrons revolving around the nucleus of the atom is equal to the number of positively charged protons inside the nucleus of the atom.

Atomic number Z

The number of positive protons in the nucleus of an atom of an element.

It is written at the lower left side of the element symbol.

$_{1}H$

Mass number A

The sum of the numbers of protons and neutrons in the nucleus of an atom of an element.

It is written at the upper left side of the element symbol.

$^{1}_{1}H$

Number of neutrons (=) mass number A (−) atomic number Z

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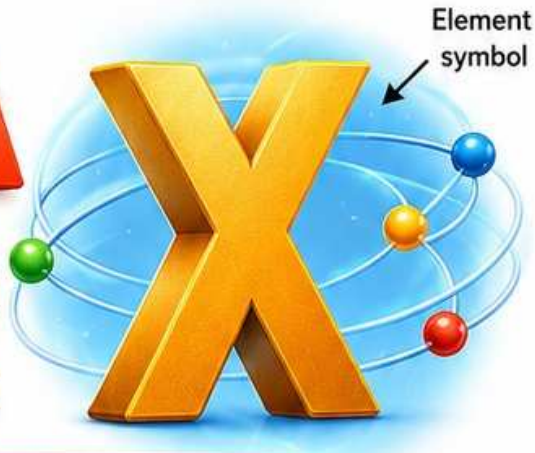
Mass number (A) =

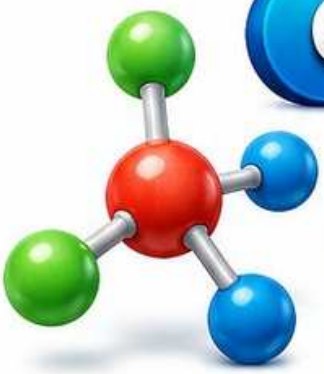
Number of protons + Number of neutrons

Atomic number (Z) =

Number of protons = Number of electrons



Compound molecule



Molecular formula

It is a symbolic formula that expresses the type and number of atoms of elements that form the molecule.

Chemical Symbols of Elements

Examples of symbols of some famous elements

Element	Symbol	Element	Symbol	Element	Symbol
Hydrogen	H	Potassium	K	Iodine	I
Helium	He	Magnesium	Mg	Carbon	C
Mercury	Hg	Lithium	Li	Calcium	Ca
Oxygen	O	Zinc	Zn	Chlorine	Cl
Fluorine	F	Nitrogen	N	Copper	Cu
Iron	Fe	Neon	Ne	Chromium	Cr
Phosphorus	P	Sodium	Na	Argon	Ar
Lead	Pb	Boron	B	Aluminum	Al
Sulphur	S	Beryllium	Be	Gold	Au
Silicon	Si	Bromine	Br	Silver	Ag

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Metals and Nonmetals

Properties of Metals

The last energy level in their atoms ends with **1, 2** or **3** electrons.

Sodium atom
$_{11}Na$

All of them are solids:

Examples :

- Sodium Na
- Copper Cu
- Zinc Zn
- Silver Ag
- Iron Fe
- Calcium Ca
- Potassium K

Except mercury Hg element, "the only liquid metal".

Mercury

They have metallic luster (shiny).

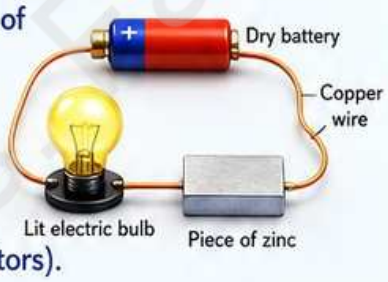
Sodium

Malleable, ductile and formable.

Copper

Good conductors of heat (thermal conductors).

Good conductors of electricity (electrical conductors).



Their melting points are high.

Properties of Nonmetals

The last energy level in their atoms ends with **5, 6** or **7** electrons, with the exception of hydrogen H (1 electron) and carbon C (4 electrons).

Chlorine atom
$_{17}Cl$

They are either solids or gases.

Examples of solid nonmetals :

- Carbon (Graphite) C
- Sulphur S
- Phosphorus P
- Iodine I

Examples of gaseous nonmetals :

- Hydrogen H
- Nitrogen N
- Oxygen O
- Fluorine F

Except bromine Br element, "the only liquid nonmetal".

Bromine

They do not have luster (opaque).

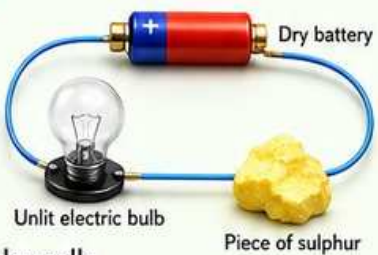
Carbon (Graphite)

No: malleable or ductile (brittle).

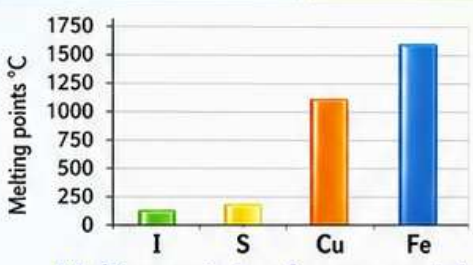
Sulphur

Bad conductors of heat.

Bad conductors of electricity, except graphite which is used in dry cells.



Their melting points are low.



Melting points of some metals and nonmetals

Key idea: **Metals** are shiny, malleable, good conductors and have high melting points.
Nonmetals are dull, brittle, poor conductors and have low melting points.

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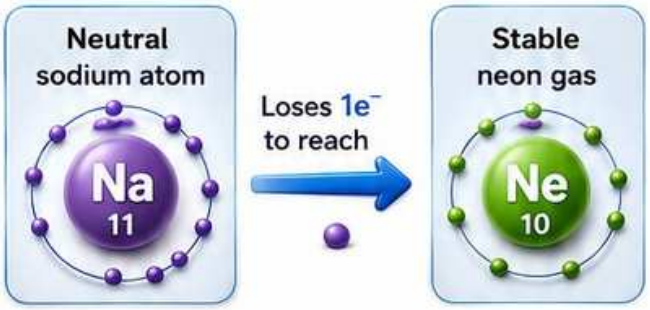
Metals

Metal atoms tend to **lose** their valence electrons to reach the stable electron configuration of the nearest noble gas with the closest atomic number that **precedes** them in the periodic table.



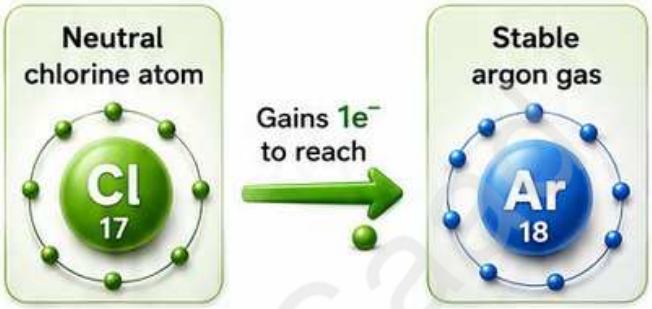
When a metal atom **loses** its valence electrons, it turns into a **positive ion (cation)** carrying a number of positive charges equal to the number of the lost electrons.

Positive ion (Cation)

It is a metal atom that has lost one or more electrons.

Nonmetals

Nonmetal atoms tend to **gain** one or more electrons according to their valencies to reach the stable electron configuration of the nearest noble gas with the closest atomic number that **follows** them in the periodic table.

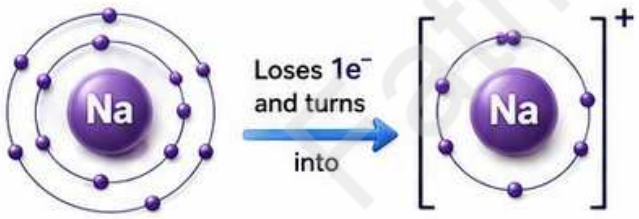


When a nonmetallic atom **gains** electrons, it turns into a **negative ion (anion)** carrying a number of **negative charges** equal to the number of the gained electrons.

Negative ion (Anion)

It is a nonmetal atom that has gained one or more electrons.

Sodium metal — $^{23}_{11}Na$



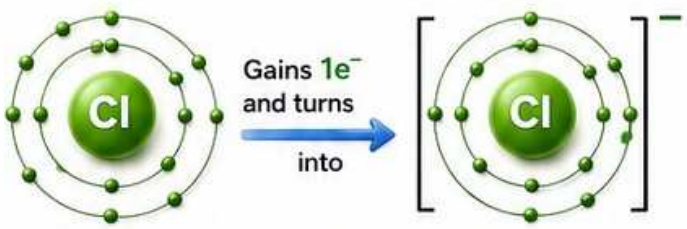
Na — Neutral sodium atom contains :
- 11 Positive charges (p)
- 11 Negative charges (e^-)

∴ Total charge = 0

Na^+ — Positive sodium ion contains :
- 11 Positive charges (p)
- 10 Negative charges (e^-)

∴ Total charge = +1

Chlorine nonmetal — $^{35}_{17}Cl$



Cl — Neutral chlorine atom contains :
- 17 Positive charges (p)
- 17 Negative charges (e^-)

∴ Total charge = 0

Cl^- — Negative chloride ion contains :
- 17 Positive charges (p)
- 18 Negative charges (e^-)

∴ Total charge = −1

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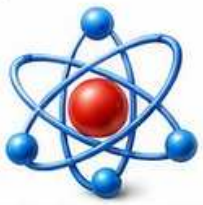


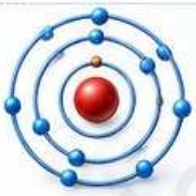
The atom	The ion
Electrically neutral.	Positively or negatively electric charged.
In the atom, the number of electrons is equal to the number of protons.	In the ion, the number of electrons is not equal to the number of protons.
Its outermost energy level is not complete with electrons, except the atoms of the noble gases.	Its outermost energy level is complete with electrons.

Positive ion (Cation)

A metal atom that has lost one or more electrons.

In the positive ion, the number of electrons is less than the number of protons.

It carries a number of positive charges equal to the number of lost electron.



The number of energy levels in the positive ion is less than the number of energy levels in its atom.

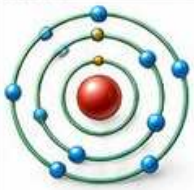
Its electron configuration is similar to the electron configuration of the closest inert gas that precedes it in the periodic table.

Negative ion (Anion)

A nonmetal atom that has gained one or more electrons.

In the negative ion, the number of electrons is greater than the number of protons.

It carries a number of negative charges equal to the number of gained electron.



The number of energy levels in the negative ion is equal to the number of energy levels in its atom.

Its electron configuration is similar to the electron configuration of the closest inert gas that follows it in the periodic table.

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First Ionic Bonding

The electrostatic attraction between : → A cation of a metal atom → and → An anion of a nonmetal atom → to form → An ionic compound molecule

How ionic bonding occurs

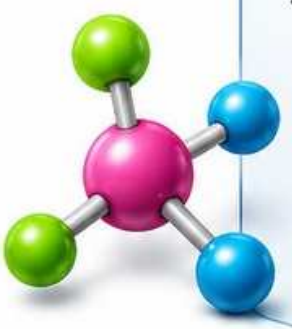
When most metals react with nonmetals :

M (Metal atom) loses its valence electrons forming M^+ (Positive ion (cation))

X^- (Negative ion (anion)) gains electrons forming X (Nonmetal atom)

Upon approaching

An electrostatic attraction occurs between the **cation** and the **anion** due to the difference in their electric charges, forming **an ionic compound**



M^+ X^-

Ionic compound molecule
(Neutrally charged)

G.R.? The ionic compound is neutrally charged.

Because in the ionic compound, the number of positive charges is equal to the number of negative charges.

Properties of ionic compounds

1. Most of them dissolve in water.

2. Their aqueous solutions (solutions in water) and their moltens conduct electricity.

3. Their melting and boiling points are high.

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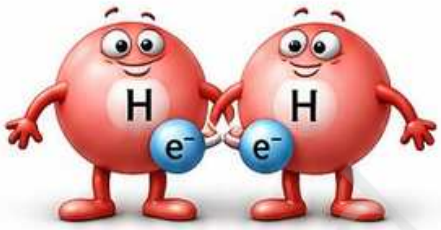
Second Covalent Bonding

It is a bond that is formed between two atoms of the same nonmetal element or between two atoms of different nonmetal elements by sharing electrons.

How covalent bonding occurs :

- Covalent bonding occurs when each atom shares a number of electrons equal to the number of electrons needed to complete its outermost energy level, without losing or gaining electrons.

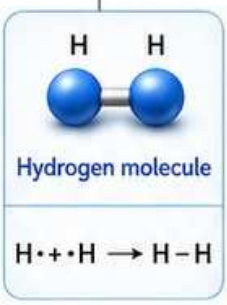


A cartoon figure illustrating covalent bonding

Types of covalent bonds

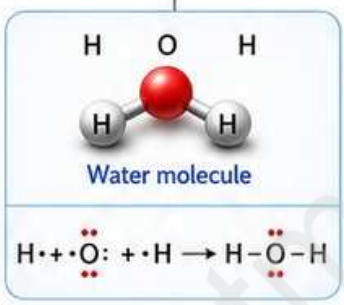
1. Single covalent bond (–)
2. Double covalent bond (=)
3. Triple covalent bond (≡)

Example



Hydrogen molecule

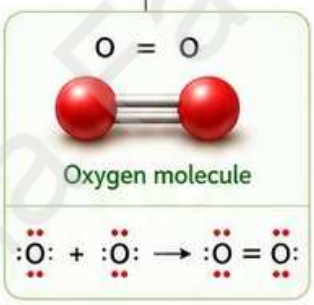
$H\cdot + \cdot H \rightarrow H-H$



Water molecule

$H\cdot + \cdot\ddot{O}: + \cdot H \rightarrow H-\ddot{O}-H$

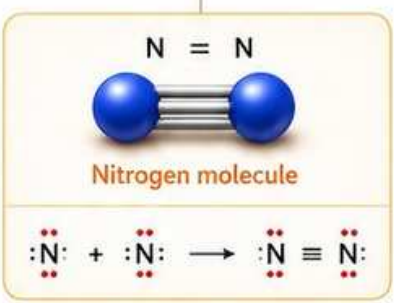
Example



Oxygen molecule

$:\ddot{O}: + :\ddot{O}: \rightarrow :\ddot{O}=\ddot{O}:$

Example



Nitrogen molecule

$:\ddot{N}: + :\ddot{N}: \rightarrow :\ddot{N}\equiv\ddot{N}:$

Properties of covalent compounds

1. Most of them do not dissolve (insoluble) in water.

2. They mostly do not conduct electricity.

3. Their melting and boiling points are low.

Properties of ionic compounds and properties of covalent compounds.

Properties of ionic compounds	Properties of covalent compounds
Most of them dissolve in water.	Most of them do not dissolve in water.
Their aqueous solutions and their moltens conduct electricity.	They do not conduct electricity.
Their melting and boiling points are high.	Their melting and boiling points are low.

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1 Ionic bonding and covalent bonding.

Ionic bonding

- It occurs between a positive ion of a metal atom and a negative ion of a nonmetal atom.
- It occurs by losing and gaining of electrons.
- It cannot occur between two atoms of the same element.
- It occurs as a result of the electrostatic attraction between a positive ion (cation) and a negative ion (anion).
- It results in compound molecules only (such as NaCl).

Covalent bonding

- It occurs between two atoms of the same nonmetal element or between two atoms of different nonmetal elements.
- It occurs by sharing electrons without gaining or losing.
- It can occur between two atoms of the same element (nonmetal).
- It occurs through the sharing of each bonded atom with one or more unpaired valence electrons.
- It results in element molecules (such as H_2) or compound molecules (such as HCl).

An ion can be ⟶ **Cation** (from a metal) or **Anion** (from a nonmetal).

- The following are examples of some cations and anions :

Cations (positive ions)

(Metallic element ions)

Lithium	Li^+
Sodium	Na^+
Potassium	K^+
Silver	Ag^+
Magnesium	Mg^{2+}
Calcium	Ca^{2+}
Zinc	Zn^{2+}
Barium	Ba^{2+}
Aluminum	Al^{3+}

Anions (negative ions)

(Nonmetallic element ions)

Fluoride	F^-
Chloride	Cl^-
Bromide	Br^-
Iodide	I^-
Oxide	O^{2-}
Sulphide	S^{2-}

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Atomic Group

Atomic group

An ion composed of more than one atom of more than one element.

Hydroxide group

Examples of some atomic groups, their molecular formulas and the number of carried charges

Atomic group	Molecular formula	No. of carried charges
Hydroxide	OH^-	One negative charge
Nitrate	NO_3^-	
Nitrite	NO_2^-	
Bicarbonate	HCO_3^-	
Chlorite	ClO_2^-	
Ammonium	NH_4^+	One positive charge
Carbonate	CO_3^{2-}	Two negative charges
Sulphate	SO_4^{2-}	
Sulphite	SO_3^{2-}	
Phosphate	PO_4^{3-}	Three negative charges

A simple method to remember the charges of the atomic groups to be studied

Most of atomic groups → **−1**

Except ammonium group (+1)

3 specific atomic groups (Carbonate, Sulphate, Sulphite) → **−2**

Phosphate group → **−3**

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Acids and Alkalis

Acids

Are substances that dissolve in water and give positive hydrogen ions H^+

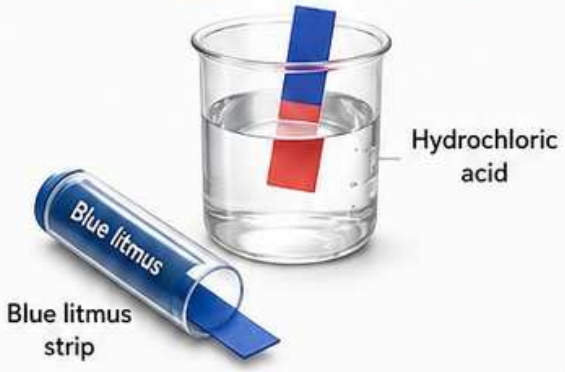
Alkalis

Are substances that dissolve in water and give negative hydroxide ions OH^-

How can you differentiate between ? **An acid solution and an alkali solution by using litmus strips.**

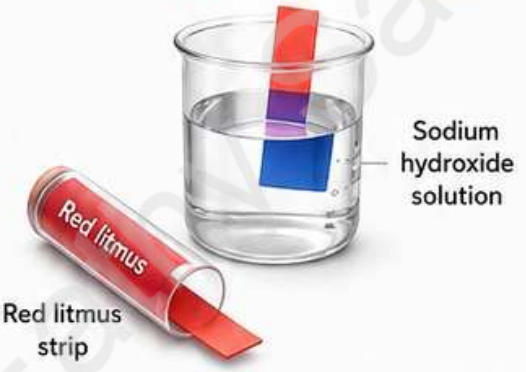
Acid solution

Turns blue litmus strip to red



Alkali solution

Turns red litmus strip to blue



Reactions of acids with alkalis

Acid → reacts → with → Alkali → forming → Salt + Water

There are

Acidic gases that change the colour of blue litmus strip to red.

For example: Carbon dioxide gas CO_2

Basic gases that change the colour of red litmus strip to blue.

For example: Ammonia gas NH_3

Gaseous elements that do not change the colour of the indicators.

For example:
- Hydrogen gas H_2
- Oxygen gas O_2
- Nitrogen gas N_2

Chlorine gas removes the colour of litmus strip (bleaches it)

Except chlorine Cl_2 which removes the colour of both litmus strips (bleaches both of them).

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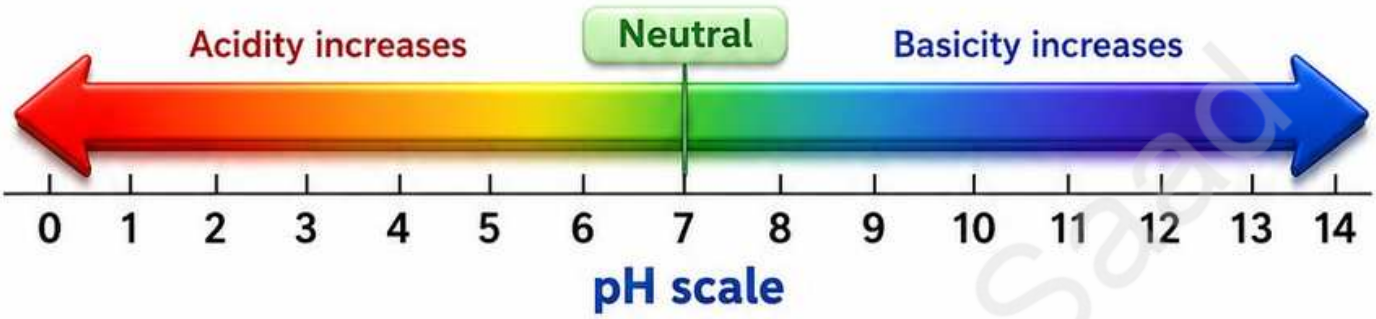
Potential of Hydrogen pH

Potential of hydrogen pH

A scale ranging between the values 0 to 14, used to determine the acidity and the basicity of solutions.



pH scale

Type of solution	Acidic	Neutral	Alkaline
pH value	Less than 7	Equal to 7	Greater than 7

Metals and Nonmetals Oxides

Metal oxides

Oxides produced from the burning of metals in the presence of oxygen are mostly known as basic oxides and some of them dissolve in water forming alkalis.

Basic oxides

Metal oxides, some of which dissolve in water forming alkalis.

Nonmetal oxides

Oxides produced from the burning of nonmetals in the presence of oxygen are mostly known as acidic oxides, which dissolve in water forming acids.

Acidic oxides

Nonmetal oxides that dissolve in water forming acids.

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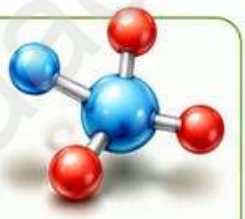
Salts

Most salts are ionic compounds formed through the reactions of alkalis with acids

- Any salt is formed by the combination of an alkali cation with an acid anion, as illustrated in the following diagram:

Taking into account that :

- The total charge of the salt formula equals zero.
- When the same atomic group is repeated in the molecular formula of the compound, the atomic group formula is written between round brackets (parentheses) with the number of repetitions below them to the right.



Salt is formed as a result of the combination of

Ions of two elements

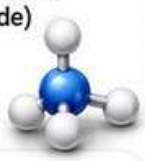
- a positive ion of a metal atom (+) — Such as: Sodium ion Na^+
- a negative ion of a nonmetal atom (−) — Such as: Chloride ion Cl^-

→ $NaCl$ (Sodium chloride)

An ion of an element and an ion of an atomic group (or)

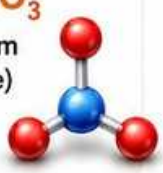
- a positive ion of an atomic group (+) — Such as: Ammonium group ion NH_4^+
- a negative ion of a nonmetal atom (−) — Such as: Chloride ion Cl^-

→ NH_4Cl (Ammonium chloride)



- a positive ion of a metal atom (+) — Such as: Sodium ion Na^+
- a negative ion of an atomic group (−) — Such as: Nitrate ion NO_3^-

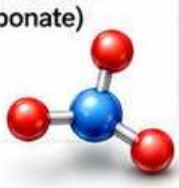
→ $NaNO_3$ (Sodium nitrate)



Ions of two atomic groups

- a positive ion of an atomic group (+) — Such as: Ammonium group ion NH_4^+
- a negative ion of an atomic group (−) — Such as: Carbonate group ion CO_3^{2-}

→ $(NH_4)_2CO_3$ (Ammonium carbonate)



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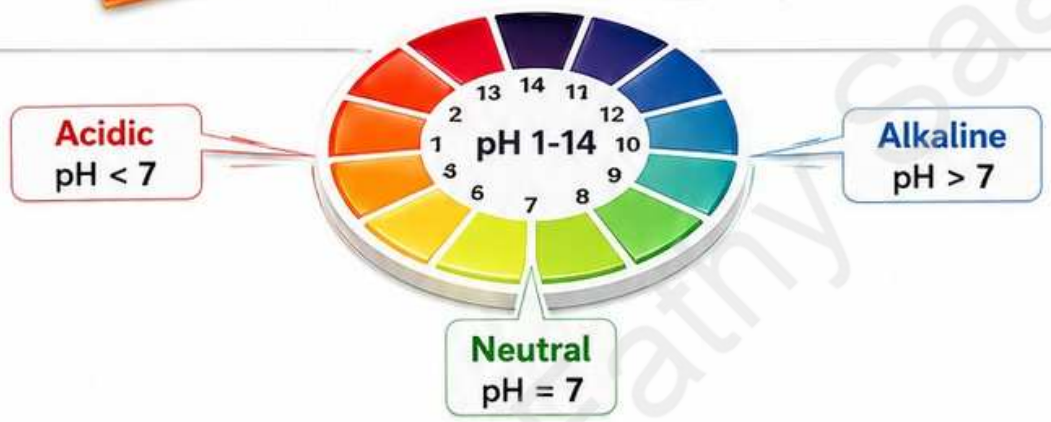
Salt solutions are classified according to their pH value into

Acidic solutions	Neutral solutions	Alkaline solutions
pH less than 7	pH equal to 7	pH greater than 7
Such as	Such as	
Ammonium chloride solution	Sodium chloride solution	Sodium carbonate solution
NH_4Cl	$NaCl$	Na_2CO_3
pH < 7	pH = 7	pH > 7



there are two types of changes in the substance, and these are

Physical changes

Physical change

A change in the state or shape of a substance without changing its chemical composition.

Example

Melting of ice

Chemical changes

Chemical change

A change that results in new substances with chemical properties different from those of the original substances.

Example

Wood combustion

Manaheg

Prepared by Ms. Fatma Fathy Saad

فيديو شرح الدرس موجود علي قناتنا علي اليوتيوب

Manaheg YouTube Channel

WhatsApp: 01274112011

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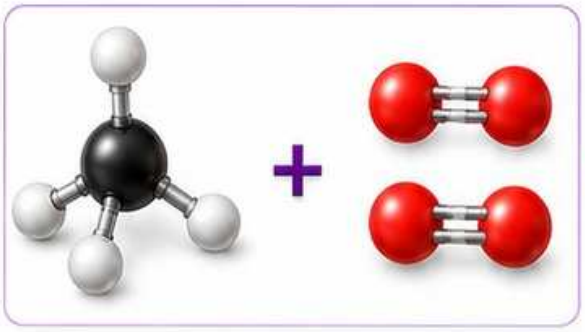
Chemical Reactions

The mechanism of the chemical reaction

Chemical reaction — A process involving **change of** — **Chemical substances (Reactants)** — **To** → **Other chemical substances (Products)**

Step one 1

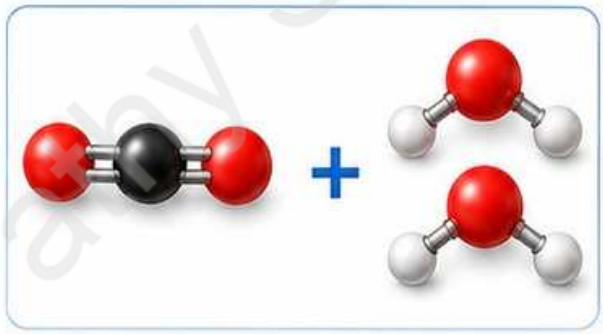
Breaking the bonds between the atoms of the molecules of **the reactants**



Breaking bonds between the atoms of the reactants molecules

Step two 2

Atoms are rearranged and combined together with new bonds to form **the products**



Formation of new bonds between the atoms of the product molecules

Chemical reaction

The process of breaking the bonds between atoms of the reacting substances (**reactants**) and forming new bonds between atoms of the produced substances (**products**).

Indications of the occurrence of a chemical reaction

— The indications of the occurrence of a chemical reaction include —

1. Formation of precipitate
2. Evolution of gas
3. Colour change
4. Emission of light and heat
5. Emission of odour
6. Change in consistency

Ms. Fatma Fathy Saad

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INDICATIONS	CHEMICAL REACTION	INDICATION OF OCCURRENCE OF REACTION
1 Formation of precipitate	Adding **silver nitrate solution** $AgNO_3$ to sodium **chloride solution** **NaCl**	Formation of a **white precipitate** of **silver chloride** **AgCl** which does not dissolve in water and its colour is changed into **violet** when it is exposed to sunlight
2 Evolution of gas	Adding **dilute hydrochloric acid** HCl to a strip of magnesium **Mg**	Formation of **hydrogen gas** H_2 bubbles
3 The change of the colour of the substance	Placing a plate of **zinc Zn** in a **copper sulphate solution** $CuSO_4$	The disappearance. of the **blue colour** of the **copper sulphate solution,** due to the formation of the colourless zinc sulphate solution $ZnSO_4$, and **reddish-brown copper** is deposited over the zinc plate
4 Emission of light and heat	Burning a **magnesium strip** **Mg** in the air	• The glow of the strip with a **bright light** accompanied by **heat emission.** • The strip converts into a **white powder** of magnesium oxide **MgO** which is soluble in water.

An ion can be ·····→ **Cation** (from a metal) or **Anion** (from a nonmetal).

Cations (positive ions) ⊕

Metal atoms or atomic groups tend to **lose electrons** and become **positively charged.**

Anions (negative ions) ⊖

Nonmetal atoms or atomic groups tend to **gain electrons** and become **negatively charged.**

Mrs. Fatma Fathy Saad

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G.R.? **Adding drops of food colouring additive to a cup of water is not a chemical reaction, even though the colour of the water changes.**

Because water only takes the colour of the additive and doesn't form new substances.

Most of the elements of the periodic table are found (at normal conditions) as monatomic molecules, such as:

Li — Lithium

C — Carbon

Except 7 elements that exist in form of diatomic molecules, which are :

H_2	N_2	O_2	F_2	Cl_2	Br_2	I_2
Hydrogen gas	Nitrogen gas	Oxygen gas	Fluorine gas	Chlorine gas	Liquid bromine	Solid iodine

Chemical equation

the word equation

1. Writing the names of the reactants on the left side of the equation
2. Linking between the reactants and the products with an arrow that indicates the direction of the reaction, and writing the reaction conditions above it, (if found)
3. Writing the names of the products on the right side of the equation

Carbon + Oxygen —(Heat)→ Carbon dioxide

Separating between each two reactants with a (+) sign

It is noted from the word equation of the previous reaction that it does not clarify :

- The physical state of the reactants.
- The ratio between the numbers of the molecules or the atoms found in the reaction mixture.

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The symbolic equation

1. Writing the symbols and the formulas of the reactants on the left side of the equation
2. Linking between the reactants and the products with an arrow that indicates the direction of the reaction, and writing the reaction conditions above it, (if found)
3. Writing the symbols and the formula of the products on the right side of the equation

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$$

Below each symbol or formula, a subscript symbol is written that expresses the physical state in which the substance exists during the reaction.

Symbolic equation

It is a symbolic representation of the chemical reaction, showing the reactants and the products by using symbols and molecular formulas, with the simplest integer ratio between the numbers of atoms or molecules entering and resulting from the reaction.

Description	Physical state	Symbol
Precipitate, salt, solid powder	solid	s
Condensed vapour, water	liquid	l
Effervescence, bubbles	gas	g
Vapour, evaporation	vapour	v
Substance that is soluble in water, acid, alkali	aqueous solution	aq

The following table showing the symbols which express the reaction conditions:

Symbol	Meaning
Δ	Heat (heating)
cat.	Using a catalyst
dil.	Using dilute acid (or dilute alkaline solution)
conc.	Using concentrated acid (or concentrated alkaline solution)

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Catalyst

A substance that increases the speed of the reaction without being consumed or changed.

Q1 Express with a symbolic equation, the reaction of sodium bicarbonate salt with dilute hydrochloric acid to form sodium chloride solution, and water in addition to carbon dioxide gas, indicating the physical states of the reactants and the products, and the reaction conditions, if found.

A

Description	Physical state	Formula and physical state
Sodium bicarbonate salt.	Solid	$NaHCO_{3(s)}$
Dilute hydrochloric acid.	Aqueous solution	$HCl_{(aq)}$
Sodium chloride solution.	Aqueous solution	$NaCl_{(aq)}$
Water.	Liquid	$H_2O_{(l)}$
Carbon dioxide.	Gas	$CO_{2(g)}$

Symbolic equation :

$$NaHCO_{3(s)} + HCl_{(aq)} \xrightarrow{\text{dil.}} NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Law of conservation of matter

Reactants

$C_{(s)}$ Carbon molecule — composed of 1 carbon atom

+

$O_{2(g)}$ Oxygen molecule — composed of 2 oxygen atoms

Products

$CO_{2(g)}$ Carbon dioxide molecule — composed of 1 carbon atom and 2 oxygen atoms

Law of conservation of matter

Matter is neither destroyed nor created from nothing, but it is transformed from one form to another.

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Manaheg YouTube Channel
WhatsApp: 01274112011
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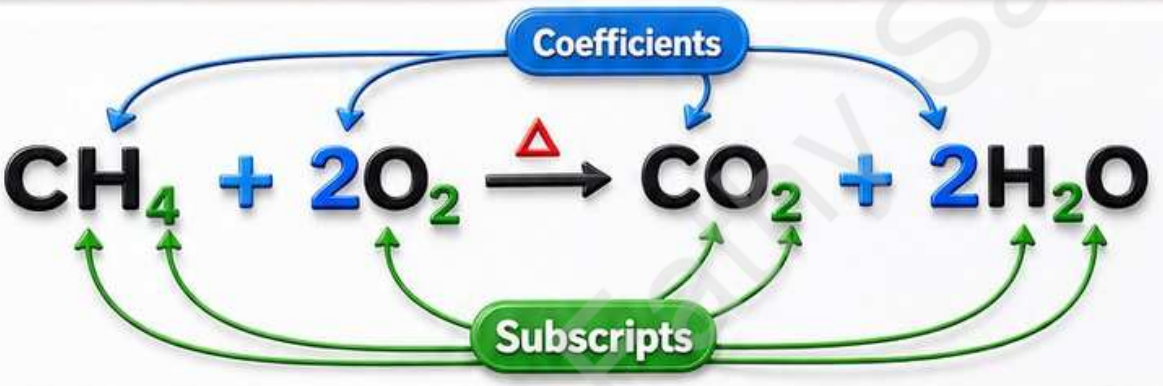
Law of conservation of mass

The total mass of the substances involved in the chemical reaction is **equal** to the total mass of the substances resulting from it.

Balanced symbolic equation

A symbolic chemical equation in which the number of atoms of each element of the reactants is equal to the number of atoms of the same element in the products.



Coefficients

The numbers that precede the symbols of the elements or the molecular formulas of the compounds in the balanced symbolic equation.

Subscripts

The numbers located below the symbols of the elements that make up the molecule and represent the number of atoms in a single molecule.

Take care :

In the balanced symbolic equation :

- The coeffficients represent the simplest integer ratio at which the reactants react together to form the products.
- The coefficient (or the subscript) is not written if it is equal to 1

Notes

- The total number of atoms of each element in the reactants must be equal to the total number of atoms of the same element in the products.
- The sum of the subscripts of the atoms of the reactants does not have to be equal to the sum of the subscripts of the atoms of the products.
- The sum of the coefficients of the reactants molecules does not have to be equal to the sum of the coefficients of the products molecules.

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How to balance the symbolic equation

Application

Step 1 Write the correct molecular formulas of the reactants and the products in the form of a symbolic equation.

$$N_{2(g)} + H_{2(g)} \longrightarrow NH_{3(g)}$$

Step 2 Comparing the number of atoms of each element in the reactants and their number for the same element in the products.

Nitrogen + Hydrogen → Ammonia

$$N_{2(g)} + H_{2(g)} \longrightarrow NH_{3(g)}$$

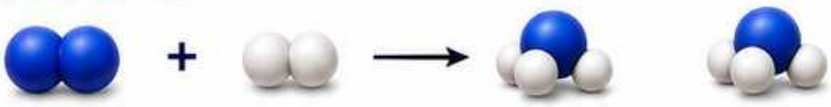
Element	Reactants		Products
N	2	≠	1
H	2	≠	3

This equation is not balanced, because the number of atoms of each element in the reactants is not equal to the number of atoms of the same element in the products

Step 3 If the numbers of atoms are not equal, adjust one of the coefficients that precede the molecular formulas of the compounds or the symbols of the elements and repeat the process of counting and comparing the numbers of the atoms.

To equalize the numbers of nitrogen atoms :

multiply the coefficient of NH_3 × 2 as follows:



$$N_{2(g)} + H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Element	Reactants		Products
N	2	=	2
H	2	≠	6

The equation is still not balanced, because the number of hydrogen atoms in the reactants is still less than their number in the products

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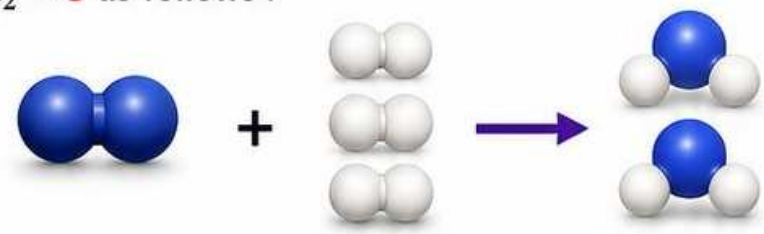
In case of that the equation is still not balanced, the **coefficients** should be adjusted even more than once.

To equalize the numbers of hydrogen atoms, multiply the coefficient of H_2 × 3 as follows :



$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Element	Reactants	=	Products
N	2	=	2
H	6	=	6

Step Checking the **balance** of the equation to ensure the numbers of atoms for all elements on both sides of the equation are equal.

$$\overset{\times}{N_{2(g)}} + \overset{\times}{3H_{2(g)}} \longrightarrow \overset{\times\ \times}{2NH_{3(g)}}$$

Reactants

Element	Calculation	Total
N	1 × 2	2
H	3 × 2	6

Products

Element	Calculation	Total
N	2 × 1	2
H	2 × 3	6

The equation became **balanced**, because the numbers of atoms of each of N and H became equal in both the reactants and the products.

Example: Balance the equation: $HgO \longrightarrow Hg + O_2$

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Dr.MoRizK